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Telephone Ext:

OFFICE MEMORANDUM

TO : Distribution

DATE June 3, 1977

FROM : H. Murphy

SUBJECT : PRELIMINARY RESULTS OF EXP. 165

SYMBOL : G-3

MAIL STOP: 981

Q = 100 gpm (2.4 bbl/min)

SUMMARY

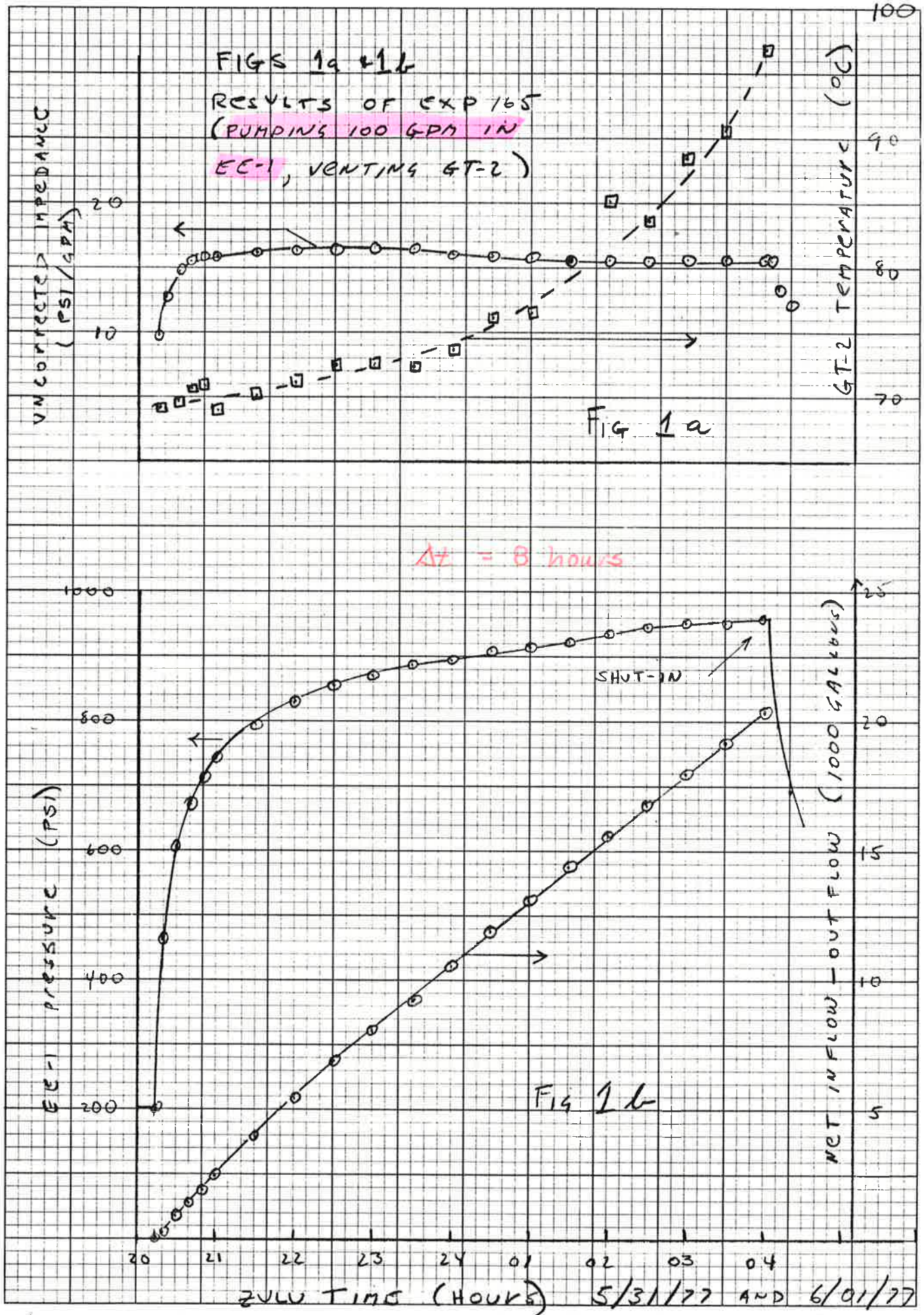
Exp. 165 was conducted on May 31, 1977. The purpose of the test was to measure the overall impedance for flow between EE-1 and the recently redrilled GT-2B path via a fracture or joint connection at 8770 ft in GT-2B. The uncorrected impedance was 15 psi/gpm, which after correction for buoyancy effects is estimated to be as high as 18 psi/gpm. It appears that the flow arriving at GT-2 is linearily diffusing from EE-1, probably via a narrow, high impedance joint.

While at a roughly constant EE-1 pressure of ∿900 psi water was lost to the formation at a constant rate of 41 gpm. This quasi-steady state was attained in only 2 hours, remarkably short compared to the time estimates for the EE-1 system existing before redrilling and fracturing. This suggests that as a result of the post redrilling fracture extension of experiment 161, several natural points had been intersected and/or activated and communicated flow. This further suggests the possibility that the GT-2B intersection is indeed with such a joint, rather than the "main," low impedance fracture.

RESULTS

Figures 1a and b present the main results. The indicated impedance was roughly constant at 15 psi/gpm* after one hour of pumping. Since buoyancy effects undoubtedly increased with time, the true impedance actually increased with time and is crudely estimated to be ∿20% higher than indicated at the end of the experiment. The GT-2 outlet temperature did exceed the local boiling point and a small back pressure of 15 psig had to be impressed to avoid boiling.

*Reported flow rates and impedance are based on the flow meter, which may be 10% low according to uncalibrated bucket measurements.



At 9030 ft, p_{gh} = 3914 psi P_W = 4874 psi (<< S_3) ~ (S_3 − 430 psi)

($S_3 + \Delta P_f$) − P_W = 5443 − 4874 = 569 psi (to do cooling!)

Figure 1b shows the EE-1 pressure and the net inflow minus the outflow volume of water i.e., the cummulative water loss to the formation. As can be seen, this latter quantity was remarkably linear, and the slope, 41.7 gpm, represents the constant rate of water loss. During the same time period the pressure was almost constant at 900 $\pm$ 50 psi. These circumstances indicate that water diffusion from the EE-1 fracture systemwas three dimensional rather than linear, one dimensional, and further suggests that this three dimensional flowwas via communicating joints running in every direction. These joints were probably activated or intersected during the high pressure (1800 psi) fracture extension of experiment 161.

Figure 2 presents the standard $A\sqrt{k}$ analysis for the EE-1 pump-up. The top curve shows that the Western operator was not able to maintain the EE-1 injection rate exactly at 100 gpm but did average 100 $\pm$ 20 gpm. The middle curve shows the EE-1 pressure departing from a linear pressure versus $\sqrt{\text{time}}$ behavior at very low values of time and pressure, i.e., the EE-1 fracture systemwas no longer behaving like a simple linearly diffusing fracture. This is consistent with a change to a jointed system. If pressed, an $A\sqrt{k}$ of 155 cm^3 could be estimated from the early pressure data. The bottom curve shows the increase in the GT-2 vent rate. This increase is linear with $\sqrt{\text{time}}$ suggesting that unlike the flow into EE-1, the flow appearing at GT-2 is due to linear diffusion, probably via one of the activated joints. The figure indicates that there is a time delay, t_D, of 22 seconds between EE-1 pressurization and the start of increasing GT-2 flow. The diffusivity of this joint can be crudely estimated as

$$K \sim \ell^2/t_D$$

and if the joint length, ℓ, is of the same order as the inlet to outlet spacing, 100 m, then K is 400 m^2/sec and the permeability of the joint is

$$k = K\mu\beta$$

where μ and β are the viscosity and compressibility of water. Substituting values gives k = 25 darcies ($2.5 \times 10^{-11} m^2$) and the joint width, w, is $\sqrt{12k}$ or 0.02 mm.

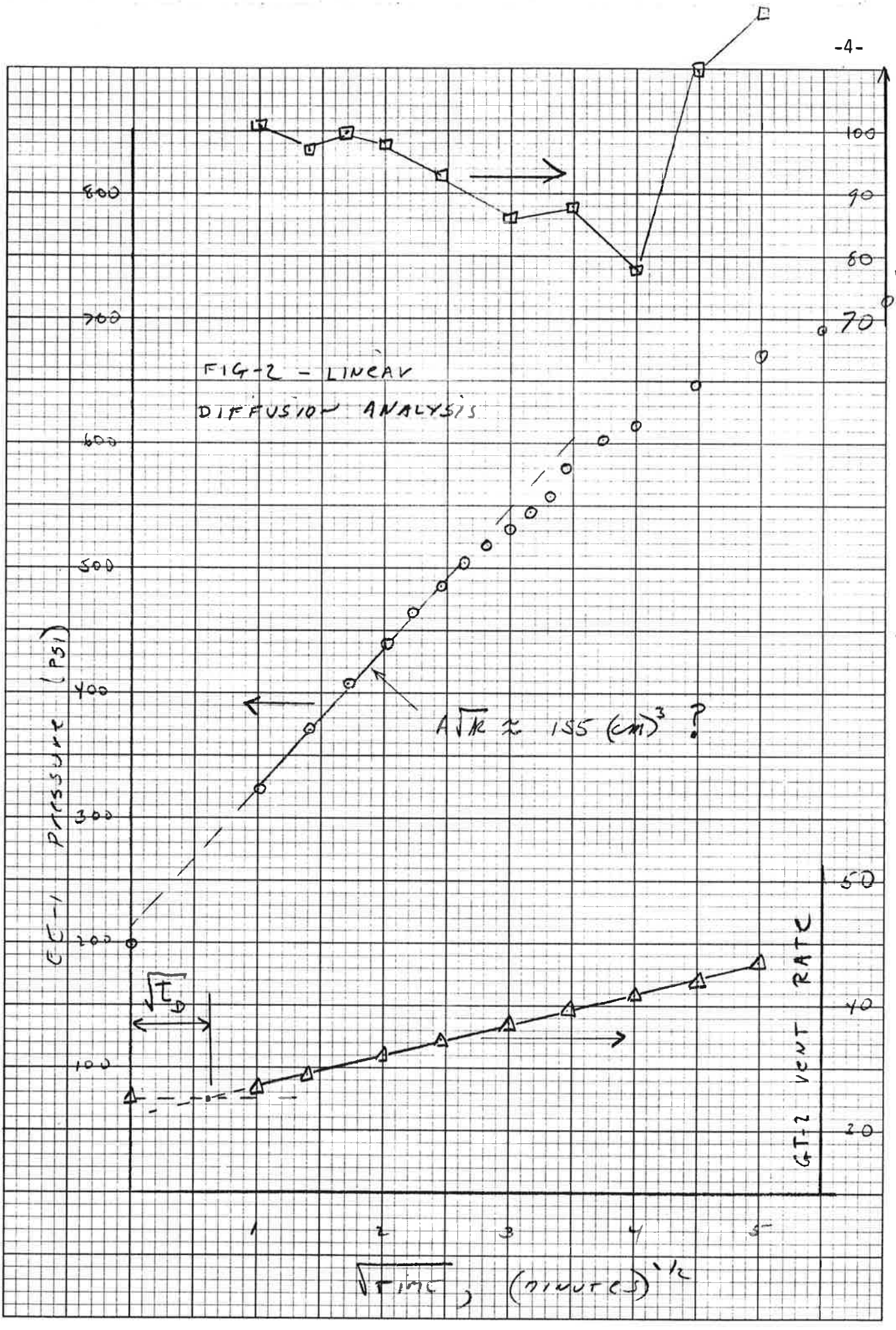


FIG-2 - LINEAR DIFFUSION ANALYSIS

If the plane of the joint is roughly square, then this width can also be estimated from the impedance, which, when expressed in psi per gpm, is

$$\text{IMPEDANCE} = 15 \text{ psi/gpm} = \frac{0.015}{[w(\text{mm})]^3}$$

This provides an independent estimate of 0.1 mm for the fracture width. On an order of magnitude basis the two estimates are at least roughly comparable. Both estimates indicate that the joint is certainly not "self-propped," quite possibly still partially sealed with alteration products. A better, low impedance connection, would probably be obtained by drilling on to the main fracture or possibly by chemical treatment of the joint. Based upon our early experiences concerning the resealing of fractures or joints at the bottom of EE-1 and GT-2 it is quite likely that many of the activated joints will also reseal, particularly if alteration products are present. If we decide to keep the present connection it would be advisable to periodically flow from EE-1 to GT-2 to keep the connection flushed and open.

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ROUGH DRAFT

To: J. Tester 6/10/77

From: H. N. Fisher and H. Murphy

SUBJECT: Preliminary Analysis of Exp. 166, 8/2/77

Symbol: G-3

Mail Stop 981

INTRODUCTION:

Exp. 166, performed on July 2 and 3 of 1977, consisted of two phases. The first was a pressurization of the GT-2B wellbore between a packer set at 8746 and the hole bottom at approximately 8770 ft. This pressurization was intended to improve the connection between GT-2B and EE-1. The second phase was a pressurization of EE-1 to measure the flow characteristic of the system. The initial slope of the pressure curve for the EE-1 fracture at constant flow (120 gpm) gives an $A\sqrt{k}$ value of 153 cm^3, Fig. 2. After 20 hours of pumping into EE-1 at 120 gpm, the EE-1 pressure was 1000 psi. At this time the permeation loss was approximately 22 gpm (or 1.2×10^7 gpy) and the EE-1 to GT-2 impedance was 10.3 gpm.

DESCRIPTION OF EXPERIMENT

Figure 1 summarizes the main events of Exp. 166. At 8:40 Zulu time on June 2 pumping was started at 0.8 bbl/min into GT-2B; at 8:50 the rate was increased to 3.3 bbl/min. The pressure reached 1650 psi at this rate. At 11:30 Z the pumping rate into GT-2B was increased to 5.17 bbl/min and the pressure increased to approximately 1770 psi. At 11:26 Z GT-2 was shut-in and vented at 12:40 Z. During this phase 3.48×10^4 gal were pumped into GT-2. Small flow out of the GT-2 annulus was observed. These increased gradually from zero to 14.3 gpm at shut-in. At an average of 7 gpm this is $.16 \times 10^4$ gal returned thru the annulus or 3.32×10^4 gal in the fracture system.

At 19:00 Z the EE-1 pressure had decayed to 120 psi and the first measurement, since venting, of the GT-2 out flow were made. Approximately 33 gpm were flowing out of GT-2 at six hours after venting. Somewhat more than one third (1.2×10^4 gal) of the water pumped into GT-2 had returned at this time. At 19:25 Z the 120* gpm pump into EE-1 began. This rate was continued until 19:00 Z 6/3/77 when EE-1 was shut-in. During this phase the EE-1 pressure reached 1000 psi and the GT-2 flow reached 97.06 gpm.

* G-3/77/242 (exp 164, 165, 166), Tester